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SYSTEMATIC REVIEW

PROXIMAL EXERCISES ARE EFFECTIVE IN TREATING PATELLOFEMORAL PAIN SYNDROME: A SYSTEMATIC REVIEW

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ABSTRACT

Background: Patellofemoral pain syndrome is a common disorder of the knee with multifactorial aetiology. Multimodal treatment, including exercise therapy, has been shown to be effective in the treatment of patellofemoral pain, although some patients continue to experience pain and dysfunction despite treatment. To address this, recent research has started to investigate the lumbo-pelvic and hip girdle in patellofemoral pain.

Purpose: The aim of this systematic review was to investigate the effectiveness of proximal exercises, compared with knee exercises, for patients with patellofemoral pain, in improving pain and function.

Methods: A computer-based search (*population*: patients with patellofemoral pain, *intervention*: proximal [hip or lumbo-pelvic] exercises, *comparator*: knee exercises, *outcome*: self-reported pain and/or functional questionnaire) was undertaken. Medline, Embase, CINAHL, SportsDiscus, Cochrane Library and PEDro were searched for studies published between January 2011 and January 2013. The included studies were appraised independently using the McMaster Critical Review Form for Quantitative Studies. Data was extracted for the exercise prescription and applicable outcome measures, and a descriptive analysis undertaken.

Results: Eight studies (three randomized controlled trials, one clinical controlled trial, three cohort studies and one case series) of moderate to high methodological quality met the inclusion criteria. Proximal exercise programs showed a consistent reduction of pain and function in the treatment of patellofemoral pain. Knee exercise programs had variable outcomes.

Conclusion: Proximal interventions provide relief of pain and improved function in the short and long term and therefore physical therapists should consider using proximal interventions for treatment of patellofemoral pain.

Keywords: exercise; hip; knee; patellofemoral pain syndrome.

Level of Evidence: 3a

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a common disorder of the knee. Prevalence is estimated to be between eight and 40%, with a higher incidence in females.[1,2] PFPS routinely affects adolescents, young adults, and the athletic population.[2-5] Sufferers generally present to sports physicians and physical therapists with peri-patellar pain aggravated by activities stressing the patellofemoral joint, such as squatting, prolonged sitting, stair climbing and running.[6] The exact aetiology remains unknown but factors contributing to PFPS are thought to include: proximal and distal muscle imbalance and weakness, overuse, soft tissue tightness and poor lower limb alignment, such as increased Q angle and poor foot biomechanics.[6,7]

Conservative management is the first choice for treatment, with options including: exercise, patella taping and bracing, foot orthoses, manual therapy, electrotherapy, biofeedback and pharmacology.[7,8] There is strong evidence for the efficacy for a multimodal physiotherapy approach targeting distal and proximal influences as compared with placebo in the short term.[8] Exercise is also effective although the research into the efficacy of the remaining conservative treatments is equivocal and requires further investigation.[8] Surgical options such as arthroscopy for chondroplasty, meniscal repair, and lateral release have been used in the past, but recent studies have reported no additional benefit of surgery compared with conservative treatment.[9,10]

Exercise therapy has consistently been found to be effective in reducing pain in patients with PFPS, with programs traditionally focussing on improving quadriceps strength and vastus medialis obliquus function.[7,8,11] Despite the success of conservative treatment in many cases, some patients continue to experience pain and dysfunction, making PFPS a challenging condition to treat.[7,8,12] As such, researchers have recently investigated the influence of the proximal musculature, including the hip girdle and lumbo-pelvic region.[13,14] Hip muscle weakness and reduced dynamic postural stability have been reported in the literature as potential contributors to abnormal patellofemoral joint kinematics.[13-16] As a result there has been a recent shift towards including proximal exercises in the management of PFPS in order to decrease the load on the patellofemoral joint and normalize the kinematics.[13,15]

Two recent systematic reviews have investigated the efficacy of conservative treatment options, including exercise, on pain levels in the treatment of PFPS.[7,8] Collins et al[8] conducted a high quality review and concluded that multimodal physical therapy, addressing the entire lower limb and proximal regions, reduced pain in PFPS. They reported that the effectiveness of knee exercise programs was not improved with the addition of proximal exercises, or other interventions. In addition, they identified that core stability deficits had not been investigated in the literature. In a moderate quality review, Bolgla et al[7] reported reduced pain with hip exercises for PFPS but these interventions combined knee exercises and/or manual therapy, potentially confounding the results. They reported that quadriceps exercises (open or closed kinetic chain) alone significantly reduced pain levels in most instances. Bolgla et al[7] identified the need to investigate the effect of isolated hip strengthening for treatment of PFPS, and to investigate treatment efficacy in different patient groups. Harvie et al[17] systematically reviewed the required prescription parameters for effective exercise programs for PFPS, but did not differentiate on the area of the body being exercised. There is no available recent review of functional outcomes after exercise therapy.

Considering the recent therapeutic interest in proximal interventions for PFPS, this systematic review builds on the current evidence base for exercise and addresses the need for further high quality research into the effects of proximal-based exercise programs in the treatment of PFPS. The aim of this systematic review was to investigate the effectiveness of proximal exercises, compared with knee exercises, for patients with PFPS, in improving pain and function.

METHODS

Study design

This systematic review was guided by the PRISMA statement.[18] All prospective, experimental studies were considered if they included pain and/or functional outcome measures after proximal or knee exercise-based interventions in subjects with PFPS.

Types of Participants

Studies were considered if they involved adults or adolescents (as defined by individual studies) with a clinical diagnosis of PFPS, consistent with the inclusion criteria of previous systematic reviews on this condition.[11,17] Accurate diagnosis of PFPS remains unclear,[19] and as such the diagnostic criteria of recent reviews and research in the area guided this review. Studies were included if participants reported insidious onset of anterior or retropatellar knee pain during any of the following activities: climbing stairs, hopping, running, squatting, kneeling or prolonged sitting. Studies on subjects reporting recent knee surgery, trauma or co-existing knee pathologies (e.g., osteoarthritis, meniscal tears) were excluded.

Intervention

Experimental studies were included if any arm of the study involved an exercise program principally targeting proximal musculature of the lumbar, pelvic, and hip regions. This could incorporate strengthening, stabilizing, or stretching exercises.

Comparator

Studies were included if any arm of the study involved an exercise program principally targeting the knee joint, particularly the quadriceps. This could incorporate strengthening, stabilizing, or stretching exercises. No co-intervention (e.g. electrotherapy, taping) was permitted for either intervention or comparator.

Outcome Measures

Studies were included if they reported on functional outcome questionnaires for the knee and/or self-reported pain post intervention and for any length of follow up. Crossley et al[20] have reported that the Kujala Anterior Knee Pain Scale (AKPS) when combined with the visual analogue scale (VAS) are reliable, valid and responsive in patients with PFPS. However, various pain and functional measures have been reported in recent literature thus it was decided to include all available outcome measures for this systematic review.

Data Sources and Search Strategy

A computer-based search strategy was undertaken using the following databases: Medline, Embase, CINAHL, SportsDiscus, Cochrane Library and PEDro up until 28 January 2013. The keywords for the PICO (population, intervention, comparator, outcomes) search strategy are detailed in Table 1. Studies published between January 2011 and January 2013, in English and available in full text were considered. The full search strategy can be obtained from the authors. The most recent review on exercise for PFPS[7] reported effectiveness of both proximal and knee exercises but recommended future research should compare them. Their search concluded on 31 December 2010 and therefore the literature was searched after this date. Additional references relevant to this search were selected from the reference lists of included studies and recent systematic reviews on exercise and PFPS.[7,8,17,21] Google Scholar was examined for grey literature not found with conventional database searching.

Each investigator participated in every step of the review. After establishing the protocol collaboratively, the reviewers searched the databases independently before comparing their search results for accuracy.

Table 1. *Search strategy - PICO definitions and keywords utilized.*

	Definition	Keywords
Population (P)	Adolescents and adults with PFPS	anterior knee pain or pfps or patellofemoral pain syndrome or chondromalacia patell* or pfj*
Intervention (I)	Proximal exercise programs	hip* or gluteal* or core or hip abductor* or proximal AND exercis* or stability or strength*
Comparator (C)	Knee exercise programs	leg extens* or quadricep* or vmo or vastus medialis or knee AND exercis* or stability or strength*
Outcome (O)	Self-reported pain and/or functional questionnaire	as described in study

Titles, abstracts and, where necessary, full texts were screened for eligibility. Decisions as to which studies to include for appraisal were made together.

Critical appraisal of included studies

The McMaster Critical Review Form for Quantitative Studies[22] was used to determine methodological quality of included studies, by assessing bias within studies. McMaster utilizes 16 elements to appraise all types of experimental designs. Responses were marked as yes (one point), no or not addressed (zero points) or not applicable. The study design and associated NHMRC level of evidence[23] were also reported.

As this review compared exercise interventions, the authors established nine additional criteria that each study should describe for comprehensive interventions related to exercise: 1) reproducible description, 2) repetitions and sets, 3) frequency, 4) program duration, 5) initial instruction by qualified practitioner, 6) level of supervision, 7) review of technique during program (if not supervised), 8) progression of program, and 9) modification for pain during exercises. The reviewers conducted the critical appraisal of included studies independently and there were no disagreements on appraisal scoring.

Data extraction and analysis

The data extraction and analysis were performed collaboratively. In addition to the data extracted with the exercise appraisal (described above), the following were sought: sample characteristics (size, age, gender, and activity profile), outcome measures used, results at baseline, post intervention and any reported follow-up periods and mean differences from baseline (including statistical significance). If studies were found to be missing critical data for analysis, attempts would be made to contact the authors for further details.

Given the heterogeneity in previous reviews and the authors' clinical experience, it was anticipated there would be no homogeneity between studies and therefore we planned to analyse the data qualitatively. To enable comparison between studies, average percentage change from baseline was calculated (where possible) for significant findings in each study. This was defined as: the difference between the mean baseline and post-test/follow up scores divided by the mean baseline score and expressed as a percentage. The mean percentage change and standard deviation for each group was then calculated. Effect sizes were calculated if appropriate data was available.

RESULTS

Search Strategy

The search strategy produced eight relevant articles, with nine intervention arms, which met the inclusion criteria (Figure 1). All trials were from peer-reviewed journals, seven were experimental studies and one reported on follow up data.[24] Only Fukuda et al[24] were contacted by the authors in regards to absent post-intervention data for their study. They advised that post-intervention data were not collected as they had reported on this in a previous publication on a different group of subjects.[25] The reviewers chose to include this study, despite it not technically being an experimental trial, as they felt the follow-up data would provide useful information. No experimental protocols were identified that had not progressed to published trials.

Methodological Quality

All included articles scored moderate to high on the McMaster critical appraisal tool (Table 2). The NHMRC level of evidence was variable, with three randomised controlled trials (RCT) (level II), one clinical controlled trial (CCT) (level III-1), three cohort studies (level III-2), and one case series (level IV). Only two articles met all of the McMaster criteria. Five did not justify their choice of sample size. Reporting of the reliability and validity of outcome measures and dropouts was inconsistent. Contamination and cointervention were not addressed in three studies. Blinding of the therapist and subjects was not reported, but with exercise interventions it is difficult to do this. There was consensus between the reviewers on the appraisal results at the initial discussion.

The critical appraisal of the exercise intervention is presented in Table 3. Items were generally well reported and three studies met all desired criteria. In the remaining studies the effect of pain on program modification was not documented. Eapen and colleagues[26] did not clearly report progression of the exercises. All but one study reported appropriate repetition

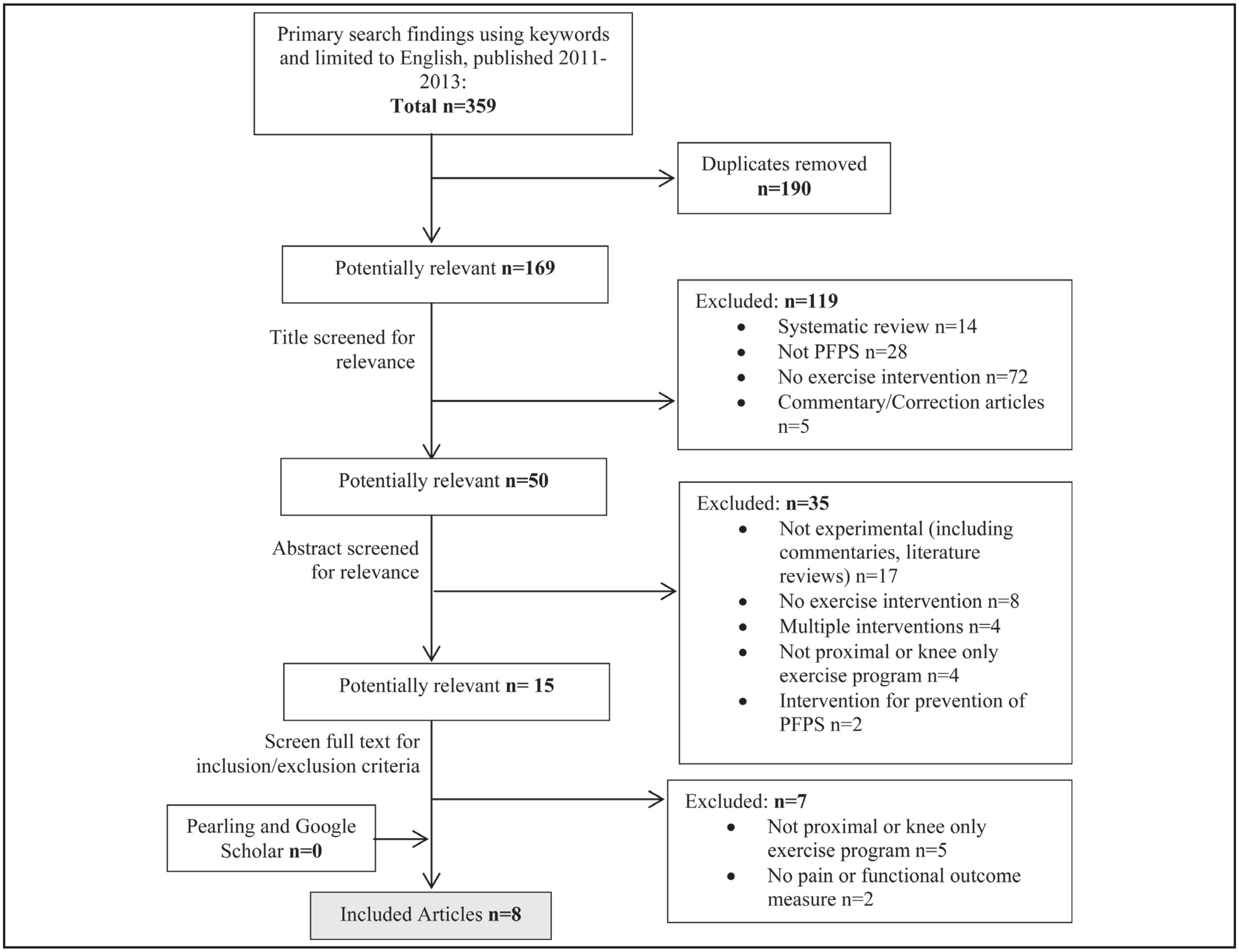

Figure 1. *PRISMA diagram.*

parameters in line with the recommendations of Harvie et al,[17] however the frequency and duration of the exercise programs were variable and generally less than recommended for PFPS exercise. In particular, only one study carried out exercises daily,[27] and four out of the eight intervention periods were of less than the recommended six weeks.

The Interventions

A summary of the nine intervention arms for the component studies is provided in Table 4.

Proximal exercises

Four studies reported on a proximal exercise intervention arm, predominantly targeting the hip muscles in single joint movements with either elastic band or weighted resistance.[27-30] Hip abduction was prescribed in all studies and only Earl et al[29] included lumbo-pelvic exercises, such as quadruped and plank exercises, as outlined in Table 4. Stretching was prescribed in two studies. All four studies reported significantly reduced pain on the VAS after the exercise program ($\bar{X} \pm SD = 3.67 \pm 1.96$ or $65.1 \pm 22.9\%$ reduction).[27-30] Three studies reported significant improvements in function using varying outcome measures ($\bar{X} \pm SD = 37.5 \pm 37\%$).[28-30] Khayambashi et al[30] reported pain was reduced at a 6 month follow up.

Knee exercises

Five studies reported on a knee exercise intervention,[24,26,28,31,32] predominantly focused on open kinetic chain quadriceps exercises. Fukuda et al[24] also

Table 2. *Methodological quality of studies using the McMaster Critical Review Form.*[22]

Authors	Study design	Level*	Item 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Score
Chiu et al[31]	C	III-2	✓	✓	✓	✓	✗	✓	✗	✗	✓	✗	✗	✓	✓	✓	✓	✓	11/16
Dolak et al[28]	RCT	II	✓	✓	✓	✓	✗	✓	✓	✗	✓	✗	✗	✓	✓	✓	✓	✓	12/16
Eapen et al[26]	C	III-2	✓	✓	✓	✓	✗	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✗	✓	13/15
Earl and Hoch[29]	CS	IV	✓	✓	✓	✓	✓	✓	✓	✓	✓	n/a	✓	✓	✓	✓	✓	✓	15/15
Ferber et al[27]	C	III-2	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	✓	13/16
Fukuda et al[24†]	FU/ RCT	II	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16/16
Khayambashi et al[30]	CCT	III-1	✓	✓	✗	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	14/16
Mason et al[32]	RCT	II	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✗	✓	✓	✗	✓	✓	11/16

* level of evidence (based on NHMRC hierarchy)[33]; C = prospective cohort; RCT = randomised controlled trial; FU = follow up study from previous RCT; CCT = controlled clinical trial; ✓ = yes; ✗ = no/not reported; n/a = not applicable

McMaster items: 1. Study purpose clearly stated; 2. Background literature reviewed; 3. Appropriate research design; 4. Sample described in detail; 5. Sample size justified; 6. Ethics approval sought; 7. Outcome measure reliability reported; 8. Outcome measure validity reported; 9. Intervention described; 10. Contamination avoided; 11. Co-intervention avoided; 12. Results reported in terms of statistical significance; 13. Appropriate analysis methods; 14. Clinical significance reported; 15. Drop-outs reported; 16. Appropriate conclusion

†Fukuda et al[24] has been classed as a follow up study of RCT as it does not report on immediate post intervention data

included calf raises, knee flexion and squat. Stretching of the lower limb was included in two studies. Mason[32] reported a significant reduction in pain on 75% of assessed activities, although initial pain levels were much lower than the other studies. Three out of four studies found a significant reduction in pain post intervention ($\bar{X} \pm SD = 36.8 \pm 26.95\%$).[26,31,32] Three studies reported on functional outcomes, all with significant improvement post intervention ($\bar{X} \pm SD = 20.5 \pm 12.2\%$).[26,28,31] Fukuda et al[24] reported reduced pain at 3 months (going upstairs only) and at 6 months (going upstairs and downstairs) only. The only improvement at 12 months was in the Lower Extremity Functional Scale score.

Proximal exercises compared to knee exercises

Only one study directly compared the effect of proximal exercises to knee exercises.[28] It was reported that the proximal exercise group had significantly greater improvement in pain at four weeks compared with the knee exercises group, but functional outcome was the same. Data were not available to calculate effect size. Fukuda et al[24] compared knee only exercises to a combined program of knee and proximal exercises, finding a significant difference between groups (favouring the combined program) for all outcome measures at three, six and twelve months. Statistical comparisons could not be completed between studies due to heterogeneity. A summary of the effectiveness of the exercise programs is presented in Table 5.

Summary

This systematic review found eight experimental studies of moderate to high methodological quality investigating the effect of proximal or knee exercise interventions (nine intervention arms) on pain and/or function in patients with PFPS. All of the proximal exercise programs improved pain and function, while 80% of the knee interventions reduced pain, and 75% improved function.

DISCUSSION

Previous systematic reviews have supported the effectiveness of exercise in reducing pain levels for

Table 3. *Appraisal of the description of the exercise intervention.*

Authors	Item 1	2	3	4	5	6	7	8	9
Chiu et al[31]	✓	✓ 4x10	✓ 3x/wk	✓ 8 wks	✓	✓	✓	n/a	✓
Dolak et al[28]	✓	✓ 3x10	✓ 3x/wk	✓ 4 wks	✓	✓ 1x/wk sup, unsup 2x/wk	✓	✓	✓
Eapen et al[26]	✓	✓ 10min	✓ 3x/wk	✓ 2 wks	✓	✓	?	n/a	?
Earl and Hoch[29]	✓	✓ 3x10 → 3x20	✓ 3x/wk + 1-2 sup/wk	✓ 8 wks	✓	✓ 8-15 sessions, 1-2x/wk	✓	✓	✓
Ferber et al[27]	✓	✓ 3x10	✓ daily	✓ 3 wks	✓	× Reviewed after 7-10 days	✓	✓	?
Fukuda et al[24]	✓	✓ 3x10	✓ 3x/wk	✓ 4 wks	✓	✓	✓	n/a	?
Khayambashi et al[30]	✓	✓ 3x20	✓ 3x/wk	✓ 8 wks	✓	✓	✓	n/a	?
Mason et al[32]	✓	✓ 10x 10sec statics	✓ 3x/day	✓ 1 wk	✓	×	×	✓ 81.5%	✓

✓ = yes; × = no; ? = not addressed; sec=seconds; min = minutes; wk(s) = week(s); (un)sup = (un)supervised

Items described: 1. Detailed description of exercise intervention 2. Sets and reps; 3. Frequency; 4. Duration; 5. Initial exercises instructed by qualified professional; 6. Supervised (and if not, was the home program reviewed during the intervention period); 7. Exercises progressed (reps/sets/resistance) during program; 8. If not supervised, was compliance monitored; 9. The effect of pain on continuing exercises.

PFPS.[7,8,11] However, this is the first systematic review that directly compares the effectiveness of proximal exercises to knee exercises for patients with PFPS, with respect to pain and functional outcomes. Proximal exercise interventions consistently improved short and long term functional and pain outcomes with greater improvements than the knee exercise interventions.

This systematic review included a range of experimental study designs with moderate to high methodological quality using the McMaster tool.[22] However this critical appraisal instrument does not include items for reporting on random allocation, blinding or sample heterogeneity. Of note, Khayambashi et al[30] used alternate allocation of subjects to groups. Random allocation would have been simple to implement and would have increased the strength of the body of evidence. The samples were small in all the intervention arms of interest (n < 30) and justification of sample size was only evident in three studies, potentially reducing the power and increasing risk of a type II error.[33] The studies also looked at different patient groups: runners, active and sedentary (and not described in two studies),[28,32] possibly affecting external validity and the ability to compare between studies. Additionally, the mean age within studies varied and the age of subjects in Mason et al[32] was considerably older than the other studies.

Generally the interventions of the component studies targeted only the proximal or knee region and

Table 4. *Description of main aspects of included studies.*

Authors	Sample Characteristics		Intervention Type	Description of Exercises	Evaluation		Results
	n	Age ($\bar{X}$±SD)			Outcome Measures	Measurement Schedule	*Including percentage change from baseline where statistically significant improvement*
Chiu et al[31]	n=9 (4 M, 5 F) active	34.33 ± 9.65	**Knee**	Warm up stretching (calf, quadriceps, hamstring, gluteal), leg press, leg extension 10RM	Pain: NRS Function: AKPS	Baseline 8 weeks	↓ **Pain:** 58.8% (p<.001) ↑ **Function:** 18.7% (p<0.001)
Dolak et al[28]	n=33 F Proximal: 17 Knee:16	Proximal: 25 ± 5 hip	**Proximal**	hip abd + ER (side lying) hip abd (standing) hip abd (sidelying) hip ER (sitting) quadruped hydrant	Pain: VAS function: LEFS	Baseline 4 weeks	***Proximal Intervention*** ↓ **Pain:** 47.9% (p<0.001) ↑ **Function:** 13.6% (p<0.001) ***Knee Intervention*** ↔ **Pain:** (p=0.88) ↑ **Function:** 9.3% (p<0.001) ***Between group comparison:*** **Pain:** proximal (VAS $\bar{X}$=2.4) less than knee (VAS $\bar{X}$=4.1) (p=0.035) **Function:** no difference between groups
		Knee: 26 ± 6	**Knee**	quad sets short arc quad straight leg raise terminal knee extension			
Eapen et al[26]	n=24 (12 F, 8 M, 4 drop out not reported) active	27.5 ± 6.6	**Knee**	isokinetic dynamometry using continuous eccentric quads action for 10mins, 10deg/seconds	Pain: PSS Function: SF-36	baseline 2 weeks	↓ **Pain:** 28.3% (p<0.001) ↑ **Function:** 29.9% (physical), 6.4% (mental), 64.3% (bodily)
Earl and Hoch[29]	n=19 F active	22.68 ± 7.19	**Proximal**	*Phase I:* abdominal draw in, side lying clams, hip abd (side lying), supine arm/leg ext, quadruped arm/leg ext, SLS, stretch (quads/calf, hamstrings) *Phase II:* SLS + hip abd (isometric), cable hip ext/flex/abd, SLS quick kicks, prone plank, side plank, mini squat, stretches *phase III:* moster walks, SLS with sport specific upper limb movement, mini lunge, SLS, step down, stretches	Pain: VAS Function: AKPS	Baseline 8 weeks 6 months	***8 weeks:*** ↓ **Pain:** 87.5% (p<0.005) - effect size 2.7 ↑ **Function:** 18.9% (p<0.005) - effect size 1.7 ***6 months:*** Statistics not reported
Ferber et al[27]	n=15 (5 M, 10 F) runners	35.2 ± 12.2	**Proximal**	Hip abd band (standing) Hip abd/ext band at 45° (standing) Completed bilaterally	**Pain:** VAS	Baseline 3 weeks	↓ **Pain:** 43.1% (p=0.01)
Fukuda et al[24]	n=54 F Knee: 26 knee+ proximal: 28 sedentary	knee: 23 ± 3 knee + proximal: 22 ± 3	**Knee**	Knee extension 90-45° (sitting) Leg press 0-45° Squat 0-45° Single leg calf raise Prone knee flexion Stretching (calf, quadriceps, hamstring, iliotibial band)	**Pain:** NPRS (0-10) for upstairs, downstairs **Function:** LEFS, AKPS	Baseline 3 months 6 months 12 months	***Knee:*** ↓ **Pain (upstairs):** 6 months (16.7%) (p<0.05) ↓ **Pain (downstairs):** 3 months (21.9%), 6 months (12.5%) (p<0.05) ↔ **Function (LEFS):** at 3 or 6 months **Reduced Function (LEFS):** at 12 months (-5.9%) ↔ **Function (AKPS):** at 3,6 or 12 months ***Knee+hip***: ↓ **Pain (upstairs):** 3 months (80.7%), 6 months (732.6%) and 12 months (53.2%) (p<0.05) ↓ **Pain (downstairs):** 3 months (72.4%), 6 months (65.5%) and 12 months (56.9%) (p<0.05) ↑ **Function (LEFS):** at 3 months (43.3%), 6 months (40%) and12 months (34.6%) (p<0.05) ↑ **Function (AKPS):** at 3 months (30.1), 6 months (24.0%) and 12 months (19.9%) (p<0.05) ***Between groups:*** Proximal+knee significantly better than knee only at 3, 6, 12 months for all outcome measures (p<0.05)
			Proximal +knee	Knee exercises (above) + Hip abduction (side lying) Hip abduction band (standing) Hip ER sitting (band) Hip ext machine			
Khayambashi et al[30]	n=28 F I: 14 bilateral sedentary	28.9 ± 5.8	**Proximal**	Hip abd (band) Hip ER (band) Completed bilaterally 5' warm up/cool down walking	**Pain**: VAS **Function**: WOMAC	Baseline 8 weeks 6 months	↓ **Pain:** ↓ at 8 weeks (82.3%) (CI -7.9, -4.9) & 6 months (78.5%) (CI -7.9, -4.3) ↑ **Function:** ↑ at 8 weeks (80.2%) (CI -54.9, -31.7) & 6 months (80%) (CI -55.9, -30)
Mason et al[32]	n=41subjects (15M, 26 F) =60 knees I:15 knees Unilateral & bilateral	45 ± 17	**Knee**	Towel extensions 10x10sec Isometric quads 10x10sec Heel lifts 10x10sec Low leg lift x10	**Pain:** VAS during 4 activities (upstairs, downstairs, step down, self-selected task)	Baseline 1 week	↓ **Pain:** upstairs (69.4%), downstairs (57.3%), self-selected (46.5%) ($\bar{X}$= 57.7%) (p<.001) ↔ **Pain:** step down (p=0.02)

n=sample size; M=male; F=female; I=intervention arm sample size; $\bar{X}$=sample mean; RM=repetition maximum; ER = external rotation; abd = abduction; ext=extension; flex=flexion; SLS=single leg stance; NRS=numerical rating scale (0-10); VAS=visual analogue scale; AKPS=anterior knee pain score (also known as Kujala); LEFS= lower extremity functional scale; PSS=patellofemoral pain severity scale; SF-36=short form health survey-36; ↑= statistically significant function improvement; ↓=statistically significant pain reduction; ↔ = no significant change reported; CI = 95% confidence interval as reported or calculated from available data.
NB: level of statistical significance as reported in each study

Table 5. *Summary of the effect of exercise for PFPS.*

Outcome	Type of program	Average Change (%)	Positive outcome								No change	
			Dolak et al[28]	Earl and Hoch[29]	Ferber et al[27]	Khayambashi et al[30]	Chiu et al[31]	Eapen et al[26]	Fukuda et al[24]	Mason et al[32]	Dolak et al[28]	Fukuda et al[24]
Pain	**Proximal**	65.1±22.9	●	●	●	●						
	Knee	36.8±26.95					●	●	●	●	●	
	Proximal + knee								●			
Function	**Proximal**	37.5±37	●	●		●						
	Knee	20.5±12.2	●				●	●				●
	Proximal + knee								●			

*Average change (±standard deviation) calculated for studies showing positive outcomes only on post-intervention data (follow up results not included in calculation)

were easily classified to either group. However, some protocols included exercises that used muscles in both regions, such as a squat which activates quadriceps, hamstrings, gastrocnemius and gluteus maximus.[34] The gluteal muscles were stretched during the warm up by Chiu et al[31] however no prescription was provided and thus it was agreed this was a minor part of the intervention. In these cases, the reviewers used their clinical experience to classify the interventions based upon the area which the majority of the exercises targeted.

The study by Fukuda et al[24] did not report on the results immediately post intervention (6 weeks), only after 3, 6 and 12 months. This study was retained in the review because it was the only knee exercise intervention to report long-term outcomes, providing valuable information for clinicians.

The proximal exercise interventions described in the studies consistently indicated positive effects, despite variations in the: duration of the program, types of exercises included and prescription parameters. Long term reduction of pain was evident,[30] but this was reported on in only one study. There was only one study that directly compared proximal exercises to knee exercises, but long term follow up results were not useful as the authors used a combined intervention after the initial four week program.[28] Variable knee exercise interventions were conducted with inconsistent results. The two studies with lowest methodological quality reported positive outcomes with knee interventions of short duration,[31,32] suggesting more caution be used when interpreting their findings because of the possibility of Type 1 errors.

Consistent with the results of previous systematic reviews, nearly all exercise interventions resulted in clinical improvements in pain and function in patients with PFPS, however it appears there are more consistent and greater improvements with proximal interventions. This may be because these exercises improve proximal and distal alignment and reduce load on the patellofemoral joint.[13,15] This is relevant in easily irritated PFPS, where increasing the load on the patellofemoral joint initially could increase symptoms such as pain and swelling. In this case, starting with proximal exercises could be of more benefit and may not produce adverse effects. Conversely, the 75-80% improvement in function and pain with knee exercises alone provides a viable treatment option for patients whom may be unable to complete proximal exercises, for example due to hip, pelvic or lumbar pain. Given the multifactorial nature of PFPS,[6,7] it is unlikely that a single intervention would result in full recovery nor that an experienced clinician would use proximal or knee exercises in isolation when treating a patient. However, the results of this systematic review support consideration of proximal interventions when treating patients with PFPS.

Most of the exercises described in the effective proximal exercise programs could be easily implemented in most clinical practices and conducted by patients at home using simple equipment such as ankle weights and elastic band resistance. Conversely, effective knee programs may have utilized isokinetic dynamometry and gym equipment, limiting accessibility and increasing the cost to access such equipment. The two knee programs that did not require specialised equipment had variable results.[28,32]

The interventions were generally well described, allowing reproducibility in the clinical situation. The current recommendation for effective exercise in PFPS is: daily exercise of two-four sets of ten or more repetitions, for six or more weeks.[17] Unfortunately, this was most likely published after the commencement of research in the included studies, resulting in the use of variable parameters of exercise prescription. More than half the studies included interventions of less than the recommended duration.[17] This is particularly evident in the knee interventions where 80% of the studies used an intervention of one to four weeks only. The final knee intervention was eight weeks. This could explain why the results were variable within this arm of the study. As no follow-up was conducted by Eapen et al[26] (two weeks) or Mason et al[32] (one week), it is unknown if the reported improvements would have been sustained with a six week intervention. Only Ferber et al[27] conducted daily exercise as recommended.

In 2004, Crossley et al[20] recommended that, combined, the VAS and AKPS/Kujala are the most reliable outcome measures in patients with PFPS. Only one study[29] adhered to these recommendations and there was inconsistency in the outcome measures used in the remaining studies. In this review, an attempt was made to quantify the size of the improvement for each intervention arm using percentage change from baseline; however due to the heterogeneity of outcome measures this suggests trends only and may not provide a valid comparison.

It would have been ideal to limit the inclusion criteria of this study to RCTs in order to improve the level of evidence. However, given the narrow publication date range and lack of high level evidence for this topic, the search justifiably included all study designs. It is also unknown if there are any relevant studies currently under review and if any have been rejected for publication. Limiting the search to English language may be a source of bias. Despite these factors, this systematic review is a synthesis of the available new evidence on the topic and is able to provide useful information to clinicians and researchers.

This review highlights the need for more high quality, experimental research (RCT/CCT) directly comparing: proximal, knee and combined proximal and knee exercises, with larger sample sizes. Subject activity levels should be reported along with short and long term outcomes, using the recommended reliable and valid outcome measures (VAS and AKPS).[20] Adolescents are affected by PFPS,[3] but no studies looked at interventions specifically within this age group. Females have been extensively included in recent research on PFPS. Males have not been studied in isolation in recent literature, and given they have been found to have different proximal mechanics to females with PFPS[16] they may respond differently to proximal interventions.

CONCLUSION

The findings of this systematic review are consistent with previous evidence reporting effectiveness of exercise for PFPS. In particular, there is consistent moderate to high quality evidence (three RCT, one CCT, three cohort studies, and one case series) that proximal interventions provide relief of pain and improved function in the short term, whereas the knee programs have variable effectiveness. Physical therapists should consider using proximal interventions for early stage treatment for PFPS.

REFERENCES

1. Boling M, Padua D, Marshall S, Guskiewicz K, Pyne S, Beutler A. Gender differences in the incidence

and prevalence of patellofemoral pain syndrome. *Scand J Med Sci Sports.* 2010;20(5):725-730.

2. Roush JR, Curtis Bay R. Prevalence of anterior knee pain in 18-35 year-old females. *Int J Sports Phys Ther.* 2012;7(4):396-401.
3. Biber R, Gregory A. Overuse injuries in youth sports: is there such a thing as too much sports? *Pediatr Ann.* 2010;39(5):286-292.
4. Myer GD, Ford KR, Barber Foss KD, et al. The incidence and potential pathomechanics of patellofemoral pain in female athletes. *Clin Biomech.* 2010;25(7):700-707.
5. Barber Foss KD, Myer GD, Chen SS, Hewett TE. Expected prevalence from the differential diagnosis of anterior knee pain in adolescent female athletes during preparticipation screening. *J Athl Train.* 2012;47(5):519-524.
6. Crossley K, Cook J, Cowan S, McConnell J. Anterior Knee Pain. In: Brukner P, Khan K, eds. *Brukner & Khan's clinical sports medicine*. 4th ed. North Ryde, N.S.W.: McGraw-Hill Australia; 2012:684-714.
7. Bolgla LA, Boling MC. An update for the conservative management of patellofemoral pain syndrome: a systematic review of the literature from 2000 to 2010. *Int J Sports Phys Ther.* 2011;6(2):112-125.
8. Collins NJ, Bisset LM, Crossley KM, Vicenzino B. Efficacy of nonsurgical interventions for anterior knee pain: systematic review and meta-analysis of randomized trials. *Sports Med.* 2012;42(1):31-49.
9. Kettunen JA, Harilainen A, Sandelin J, et al. Knee arthroscopy and exercise versus exercise only for chronic patellofemoral pain syndrome: a randomized controlled trial. *BMC Med.* 2007;5:38.
10. Kettunen JA, Harilainen A, Sandelin J, et al. Knee arthroscopy and exercise versus exercise only for chronic patellofemoral pain syndrome: 5-year follow-up. *Br J Sports Med.* 2012;46(4):243-246.
11. Heintjes Edith M, Berger M, Bierma-Zeinstra Sita MA, Bernsen Roos MD, Verhaar Jan AN, Koes Bart W. Exercise therapy for patellofemoral pain syndrome. *Cochrane Database Syst Rev.* 2003; Issue 4. Art. No.: CD003472. DOI: 10.1002/14651858.CD003472.
12. Nimon G, Murray D, Sandow M, Goodfellow J. Natural history of anterior knee pain: a 14- to 20-year follow-up of nonoperative management. *J Pediatr Orthop.* 1998;18(1):118-122.
13. Meira EP, Brumitt J. Influence of the hip on patients with patellofemoral pain syndrome: a systematic review. *Sports Health.* 2011;3(5):455-465.
14. Prins MR, van der Wurff P. Females with patellofemoral pain syndrome have weak hip muscles: a systematic review. *Aust J Physiother.* 2009;55(1):9-15.
15. Lee SP, Souza RB, Powers CM. The influence of hip abductor muscle performance on dynamic postural stability in females with patellofemoral pain. *Gait Posture.* 2012;36(3):425-429.
16. Nakagawa TH, Moriya ET, Maciel CD, Serrao FV. Trunk, pelvis, hip, and knee kinematics, hip strength, and gluteal muscle activation during a single-leg squat in males and females with and without patellofemoral pain syndrome. *J Orthop Sports Phys Ther.* 2012;42(6):491-501.
17. Harvie D, O'Leary T, Kumar S. A systematic review of randomized controlled trials on exercise parameters in the treatment of patellofemoral pain: what works? *J Multidiscip Healthc.* 2011;4:383-392.
18. Moher D, Liberati A, Tetzlaff J, Altman D, G. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Br Med J.* 2009;339(7716):332.
19. Cook C, Mabry L, Reiman MP, Hegedus EJ. Best tests/clinical findings for screening and diagnosis of patellofemoral pain syndrome: a systematic review. *Physiotherapy.* 2012;98(2):93-100.
20. Crossley KM, Bennell KL, Cowan SM, Green S. Analysis of outcome measures for persons with patellofemoral pain: which are reliable and valid? *Arch Phys Med Rehabil.* 2004;85(5):815-822.
21. Page P. Effectiveness of elastic resistance in rehabilitation of patients with patellofemoral pain syndrome: what is the evidence? *Sports Health.* 2011;3(2):190-194.
22. Law M, Stewart D, Pollock N, Letts L, Bosch J, Westmorland M. McMaster University: Critical review form - quantitative studies. 1998; http://www.srs-mcmaster.ca/Portals/20/pdf/ebp/quanreview.pdf.
23. Merlin T, Weston A, Tooher R. Extending an evidence hierarchy to include topics other than treatment: revising the Australian 'levels of evidence'. *BMC Med Res Methodol.* 2009;9(1):34.
24. Fukuda TY, Melo WP, Zaffalon BM, et al. Hip posterolateral musculature strengthening in sedentary women with patellofemoral pain syndrome: a randomized controlled clinical trial with 1-year follow-up. *J Orthop Sports Phys Ther.* 2012;42(10):823-830.
25. Fukuda TY, Rossetto FM, Magalhães E, Bryk FF, Bryk, Lucareli PRG, Carvalho NdAA. Short-Term Effects of Hip Abductors and Lateral Rotators Strengthening in Females With Patellofemoral Pain Syndrome: A Randomized Controlled Clinical Trial. *J Orthop Sports Phys Ther.* 2010;40(11):736-742.

26. Eapen C, Nayak CD, Pazhyaottyil Zulfeequer C. Effect of eccentric isotonic quadriceps muscle exercises on patellofemoral pain syndrome: an exploratory pilot study. *Asian J Sports Med.* 2011;2(4):227-234.

27. Ferber R, Kendall KD, Farr L. Changes in knee biomechanics after a hip-abductor strengthening protocol for runners with patellofemoral pain syndrome. *J Athl Train.* 2011;46(2):142-149.

28. Dolak KL, Silkman C, Medina McKeon J, Hosey RG, Lattermann C, Uhl TL. Hip strengthening prior to functional exercises reduces pain sooner than quadriceps strengthening in females with patellofemoral pain syndrome: a randomized clinical trial.[Erratum appears in J Orthop Sports Phys Ther. 2011 Sep;41(9):700]. *J Orthop Sports Phys Ther.* 2011;41(8):560-570.

29. Earl JE, Hoch AZ. A proximal strengthening program improves pain, function, and biomechanics in women with patellofemoral pain syndrome. *Am J Sports Med.* 2011;39(1):154-163.

30. Khayambashi K, Mohammadkhani Z, Ghaznavi K, Lyle MA, Powers CM. The effects of isolated hip abductor and external rotator muscle strengthening on pain, health status, and hip strength in females with patellofemoral pain: a randomized controlled trial. *J Orthop Sports Phys Ther.* 2012;42(1):22-29.

31. Chiu JK, Wong YM, Yung PS, Ng GY. The effects of quadriceps strengthening on pain, function, and patellofemoral joint contact area in persons with patellofemoral pain. *Am J Phys Med Rehabil.* 2012;91(2):98-106.

32. Mason M, Keays SL, Newcombe PA. The effect of taping, quadriceps strengthening and stretching prescribed separately or combined on patellofemoral pain. *Physiother Res Int.* 2011;16(2):109-119.

33. Samuels ML, Witmer JA. *Statistics for the life sciences.* 3rd ed. Upper Saddle River, New Jersey: Pearson Education, Inc.; 2003.

34. Isear JA, Erikson JC, Worrell TW. EMG analysis of lower extremity muscle recruitment patterns during an unloaded squat. *Med Sci Sports Exerc.* 1997;29(4):532-539.